BOSCH REACTION FEASIBILITY STUDY

Brief Recap of Bosch Reaction

The Bosch reaction is as follows:

CO2 + 2H2 🡪 C + 2H2O

This reaction is a combination of two separate reactions. Firstly, the reverse water gas shift reaction:

CO2 + H2 🡪 CO + H2O

and secondly, the following reaction:

CO2 + 2H2 🡪 C + 2H2O

If the Bosch reaction was used in a space station, the water produced would then be electrolyzed to form hydrogen and oxygen. The oxygen would be released back to the atmosphere in the station and the hydrogen would be kept for use as a feed to the Bosch reactor. The reaction requires an iron catalyst and temperatures of at least 530˚C. Other possible catalysts include cobalt, nickel or ruthenium.

The main problems that would be faced when using the Bosch reaction in a space station are:

* Difficulties maintaining the high temperature
* Carbon deposits foul catalyst

Since there is a large power source available on the Mars station, the first problem above can be ignored; there will easily be enough energy to maintain the temperatures and, provided sufficient insulation is installed on the reactor, the heat transfer to the atmosphere in the station should be negligible.

The second problem is more serious. Carbon produced by the reaction will be deposited on the catalyst’s surface, eventually stopping it from functioning correctly. NASA investigated ways around this problem and their solution was to use removable cartridges; basically small metal capsules containing the catalyst (in the form of wire wool). Once these catalysts were spent, the cartridges were removed and replaced. There were two cartridges attached to the reactor, to allow the reactor to remain functional whilst one of the cartridges was changed.

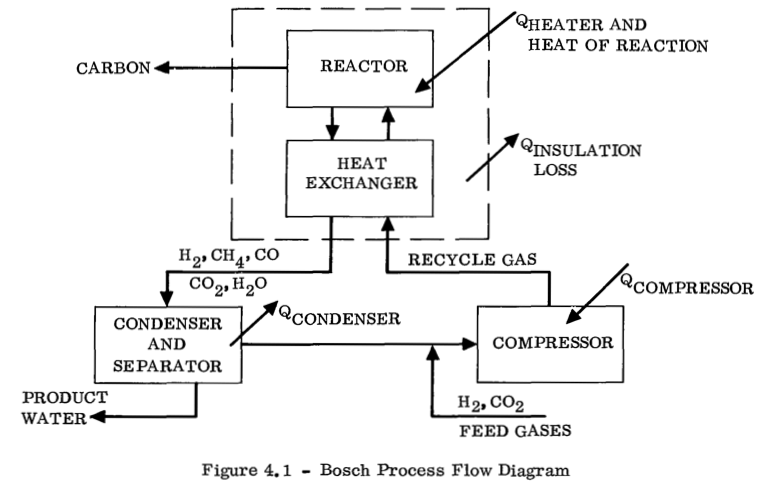
Feasibility of Using the Bosch Reaction to Convert CO2 to O2

NASA investigated, in detail, the feasibility of using the Bosch reaction to produce breathable oxygen on a space station. The results of this feasibility study are presented in a report:

“A CARBON DIOXIDE REDUCTION UNIT USING BOSCH REACTION AND EXPENDABLE CATALYST CARTRIDGES”

This report is very detailed, over 70 pages, so the main conclusions will be summarised below:

The prototype reactor built for NASA is shown below:



The reactor is essentially a packed bed reactor, operated at high temperatures. NASA’s prototype reactor used an iron catalyst in the form of steel wool. The cartridge size was arbitrarily chosen as 3 days, although it was believed that a 5 day cartridge would also be feasible.

It was important that no reaction took place outside of the cartridges, as this would mean carbon deposits would foul non-replaceable areas of the reactor, eventually preventing it from properly functioning.

Conclusions drawn from the feasibility study:

“The prototype Bosch CO2 reduction unit developed under this contract demonstrated controlled reaction with complete carbon containment in catalyst cartridges.”

Basically, NASA built a working Bosch reactor. The unit was able to remove the volume of CO2 that would be produced by a team of four people. Provided the catalyst cartridges were replaced every 3 days, the reactor would function properly.

The reactor could be scaled up to one that would process the CO2 produced by a 10 person team, as specified in the remit.

The obvious problem with the reactor is the size of the cartridges. The “three day” cartridges used with this prototype reactor were reasonably large, 9.8 inch long cylinders with external diameter 7 inches. The cartridges weighed 1.29 kg (2.85 pounds).

Since the cartridges cannot be reused, fresh cartridges would need to be supplied. For a 10 man team staying for 18 months, 456 of these cartridges would be required (before introducing any safety margin). Therefore, the weight of cartridges that would need to be provided is 588.24 kg. This would cost **£588 million/18 months**.

The NASA report concluded that “significantly more research will be required before the Bosch reactor could become a reality”. It also mentions the need to develop cartridges that can be re-used. Until this is achieved, the Bosch reactor will require substantially more re-supply equipment than, for example, a Sabatier reactor.

From previous group presentations:

One of the main problems with not using the Bosch process is that neither of the alternative processes (Sabatier and RWGS) has a closed loop for both H2 and O2. The advantage of having a closed loop of oxygen and hydrogen will need to be weighed up against the heavy re-supply masses required for a Bosch reactor.

Additional Notes:

NASA is currently investigating the Bosch-Boudouard process, which combines the first step of the Bosch reaction (the reverse water gas shift reaction) with the Boudouard reaction:

2CO 🡨 🡪 C + CO2

This reaction would require a laser to vibrationally excite the carbon monoxide molecules in order to favour the forwards reaction. This would have the advantage that the disproportionation reaction would take place between the molecules, rather than at the catalyst’s surface. A low density soot would be formed which could be easily removed from the reaction chamber, meaning that the catalyst would not need to be regenerated.

However, the Bosch-Boudouard process is still at the experimental stage; a prototype reactor has not been built yet and, for this reason, it cannot be considered for use on a Mars space station until further research is undertaken.

References:

“A CARBON DIOXIDE REDUCTION UNIT USING BOSCH REACTION AND EXPENDABLE CATALYST CARTRIDGES” – *R.F. Homes, E.E. Keller and C.D. King.*

*“NEW CONCEPTS FOR THE AVOIDANCE OR UTILISATION OF METHANE IN LIFE SUPPORT SYSTEMS” Franz Kenn, 2011*